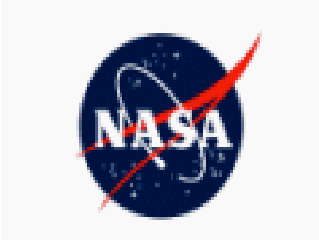


Gamma-ray Large Area Space Telescope (GLAST) Mission Operations Concept

Dennis Small

GLAST Mission Operations Manager

Thursday, June 13th, 2002

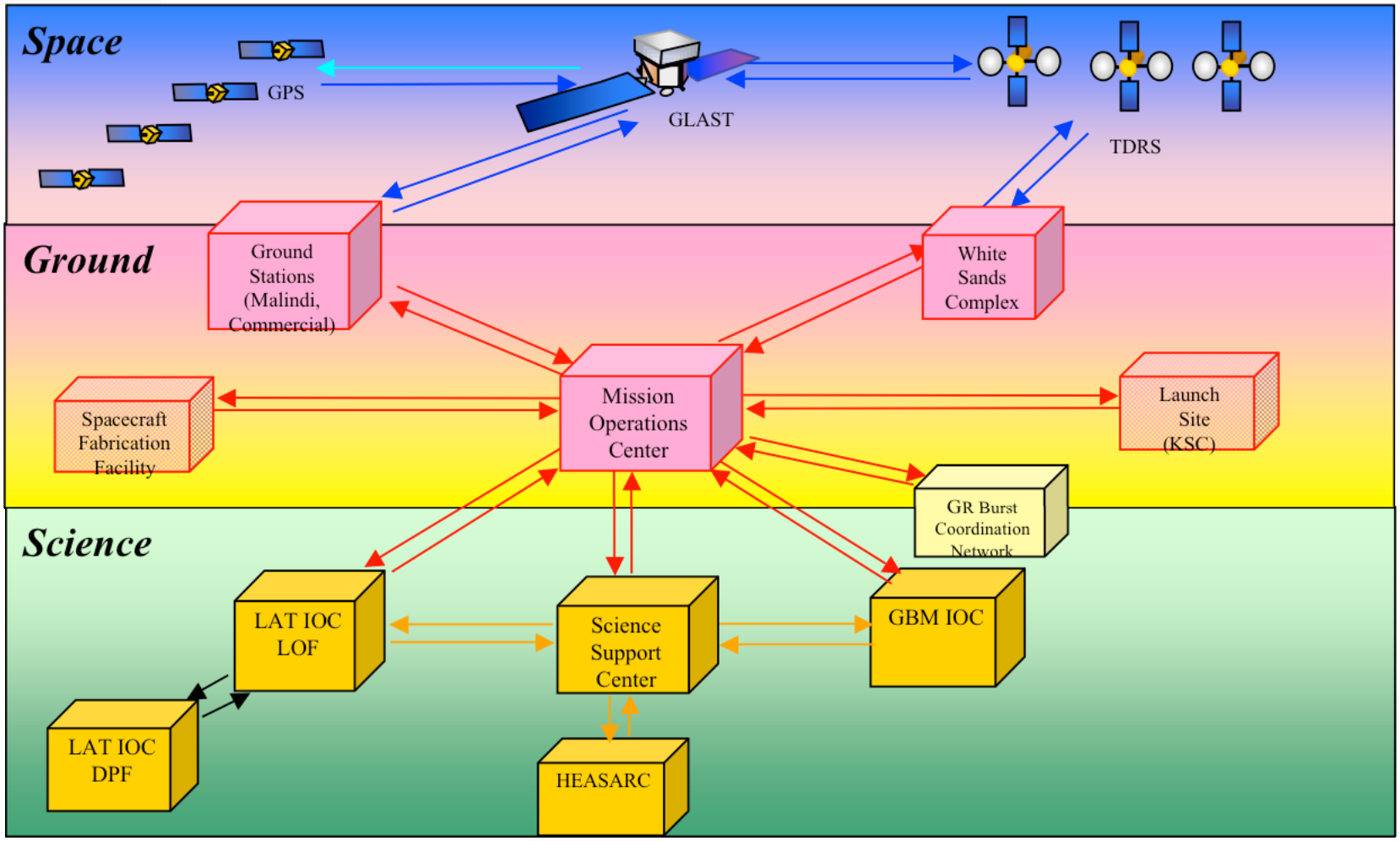
2:00 pm

Prepared By:

Ross M. Cox

ASRC Aerospace Corporation

GLAST Operations Concept
Ground System Interfaces



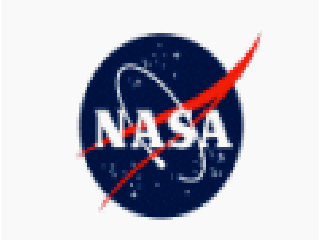
GLAST Operations Concept
AGENDA

- Introduction
  - Purpose
  - Ground Rules
  - Issue Handling
  - Definitions
  - Operations Goals
  - Presentation Content
  - Operations Element Functions by Location
- Interface Descriptions
  - Commands
  - Memory Loads
  - Telemetry
  - Memory Dumps
  - Alerts
  - Science Data
  - Scheduling
  - Databases
  - Orbit Determination
  - Trending
- Mission Phases
  - Testing
  - Launch
  - Check-out
  - Mission
  - De-orbit

ASRC AEROSPACE

GLAST Operations Concept
Introduction

- Purpose - The Request For Offer (RFO) process has clarified and provided details that changed the Operations Concept(s), therefore it is desirable to:
  - Establish baseline of understanding among all GLAST entities
  - Uncover cross-understandings
- Ground Rules/Guidelines
  - Follow the Data Products and Configurable Items through their data paths
    - Show product usage and paths
    - Describe processing and roles
    - Known Issues/Unknown Details
- Issue Handling
  - We Won't Solve It Here
    - Questions are welcome but time is limited
  - Send Email with Slide Number and Questions to Dennis and CC:Ross
    - DSmall@pop500.gsfc.nasa.gov
    - Ross.M.Cox@AkSpace.com

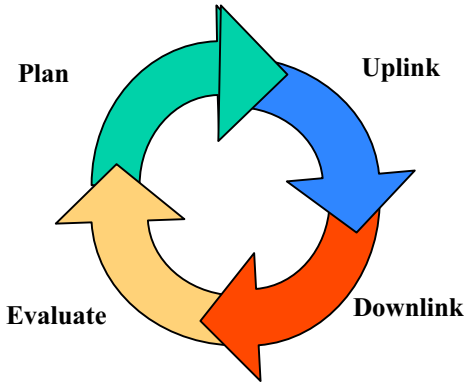


GLAST Operations Concept
Introduction

- Definitions -
  - Observatory - Integrated GLAST
  - Spacecraft - GLAST without instruments
  - Instruments - the instruments -- the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM)
  - Satellite - the Moon is a satellite -- we don't fly it (yet!)
  - Frequency - count of occurrences of piece of data or data item
  - Timing - Duration of the generation of data items within a ground system element usually with respect to some other product or event
  - Latency - Allowable lag between end of transmission and end of receipt of data item between ground system elements

GLAST Operations Concept
Introduction

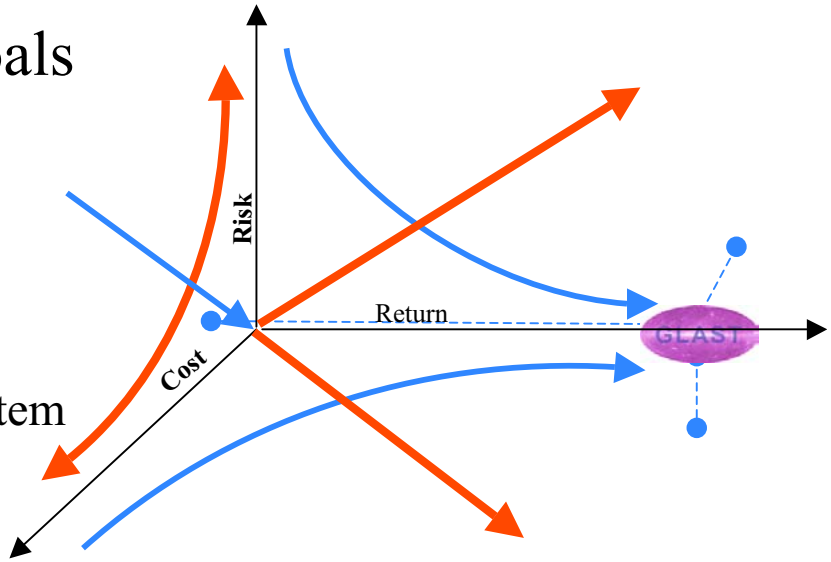
•What is Mission Operations?



- •Planning Activities
- •Uplink Activities
- •Downlink Activities
- •Evaluation Activities

• General Mission Operations Goals

- •Maximize Science Return
  - •Efficient Data Capture and Return
- •Minimize Mission Risk
  - •Smart Observatory/Smart Ground System
- •Control Lifetime Costs
  - •Automate As Much As Possible



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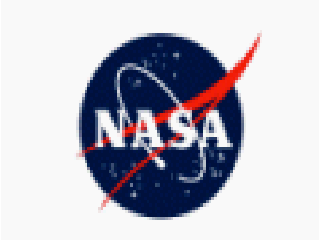


GLAST Operations Concept
Introduction

- GLAST Specific Mission Operations Goals
  - Support the scientific community in using the observatory to make significant discoveries in the following areas
    - Active Galactic Nuclei
    - Isotropic Background Radiation
    - Gamma-Ray Bursts
    - Molecular Clouds, Supernovae Remnants, and Normal Galaxies
    - Endpoints of Stellar Evolution (Neutron Stars and Black Holes)
    - Unidentified Gamma-ray Sources
    - Dark Matter
    - Solar Flares

GLAST Operations Concept
Introduction

- Two distinct methods of data collection have been identified
  - Sky Survey
    - Cover “entire sky” every two orbits
  - Pointed Observation
    - Remain “inertially fixed” on a certain target

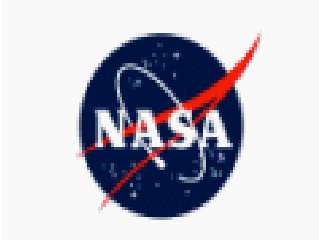
- Operations will support the mission through
  - Providing an efficient sheduling system for normal and special operations
  - Assuring data quality throughout the ground system elements
  - Performing real time commanding and monitoring as required
  - Analyzing engineering data to assess observatory health and status

GLAST Operations Concept Content

- The operations concept covers the following items
  - Commanding
  - Telemetry
  - Ground operations support and coordination
    - Scheduling
    - Databases
    - Trending
  - Special Operations
    - Burst Alerts
    - Orbit Determination
  - Anomaly Resolution
    - Safehold Alerts

GLAST Operations Concept Content

- The operations concept covers the following Mission Phases
  - Pre-Launch
  - Launch
  - Check-Out
  - Mission Phase
  - De-Orbit

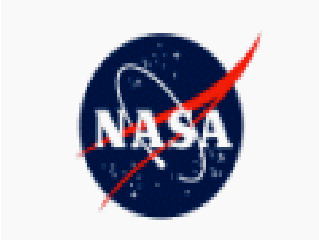


GLAST Operations Concept
Functions by Location

- Mission Operations Center (MOC)
  - Real time (R/T) operations
  - Contact scheduling
  - Low level data processing
  - Engineering analysis

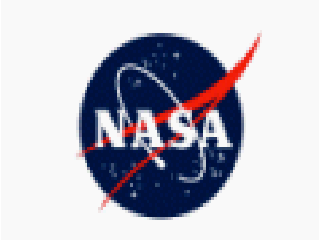
- Science Support Center (SSC)
  - Science planning and scheduling
  - Product distribution

- High Energy Astrophysics Science Archive Research Center (HEASARC)
  - Archive GLAST data and comparison to other missions



GLAST Operations Concept
Functions by Location

- LAT Instrument Operations Center(IOC) LAT Operations Facility(LOF)
  - LAT operations interface
  - Data quality reporting
- LAT IOC Data Processing Facility(DPF) {a.k.a., Science Analysis Software (SAS)}
  - High-level data processing
- GBM IOC
  - GBM operations interface
  - Data quality reporting
  - High level data processing



GLAST Operations Concept
Functions by Location

- GCN (Gamma-ray Coordinates Network)
  - Alert distribution to the world of Gamma-Ray astronomers
- Spacecraft Fabrication Facility (SFF)
  - Integrate Instruments to Spacecraft
  - Prelauch Testing
- Launch Site - Kennedy Space Center (KSC)
  - Launch Support Data flows
  - Mission Rehearsals
  - Payload(Observatory) Processing at Pad
  - Launch Voice Control

GLAST Operations Concept
Functions by Location

- White Sands Complex (WSC)
  - R/T Tracking and Data Relay Satellite* (TDRS) Operations
  - Burst transmission via TDRS Demand Access S-band (DAS) service
  - Tracking data

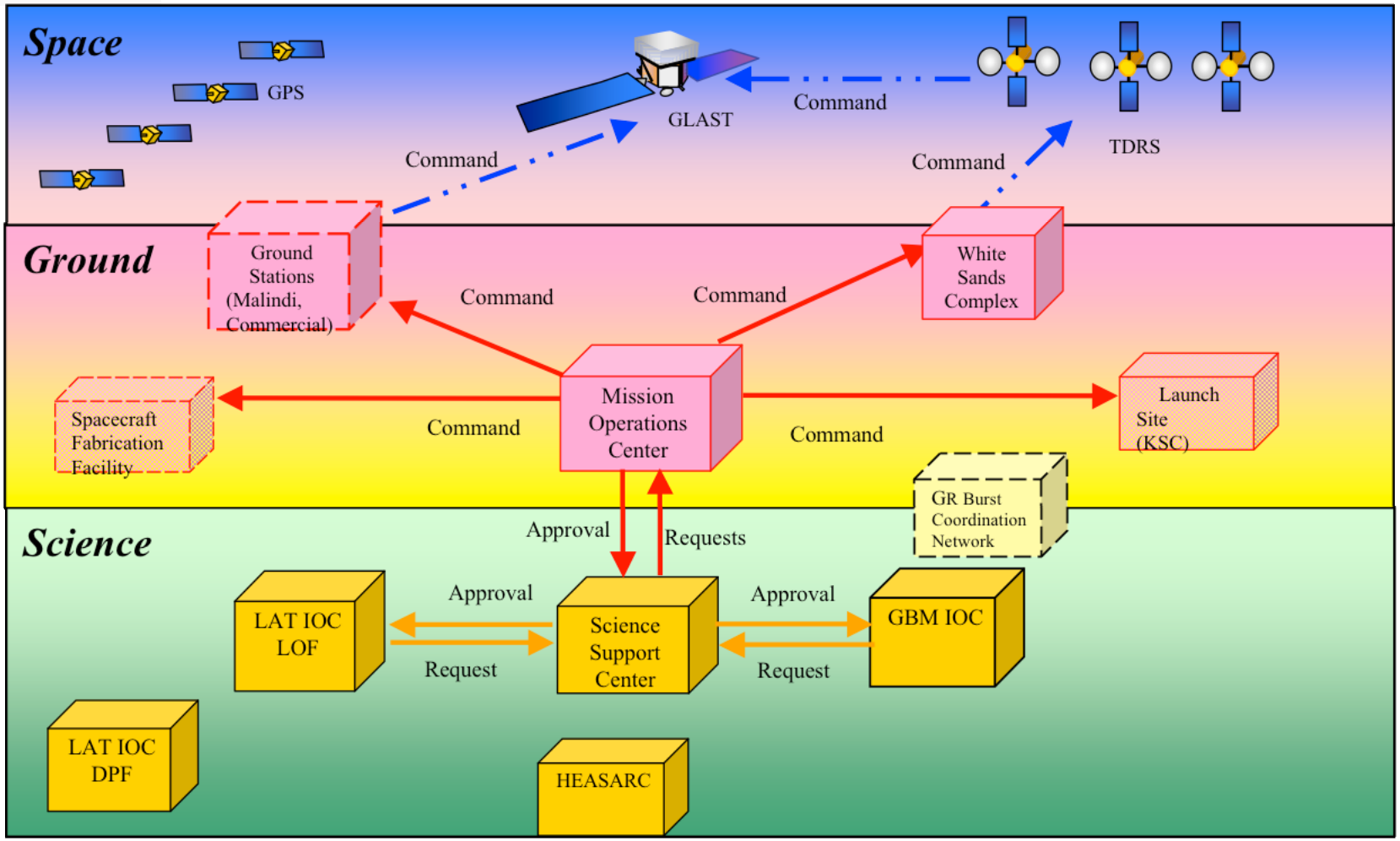
- Ground Network (GN)
  - R/T Ground-Based Operations
  - Data capture and playback
  - Tracking data

- Global Positioning System (GPS)
  - Orbit determination

*Invented before people knew the Moon was a satellite

GLAST Operations Concept

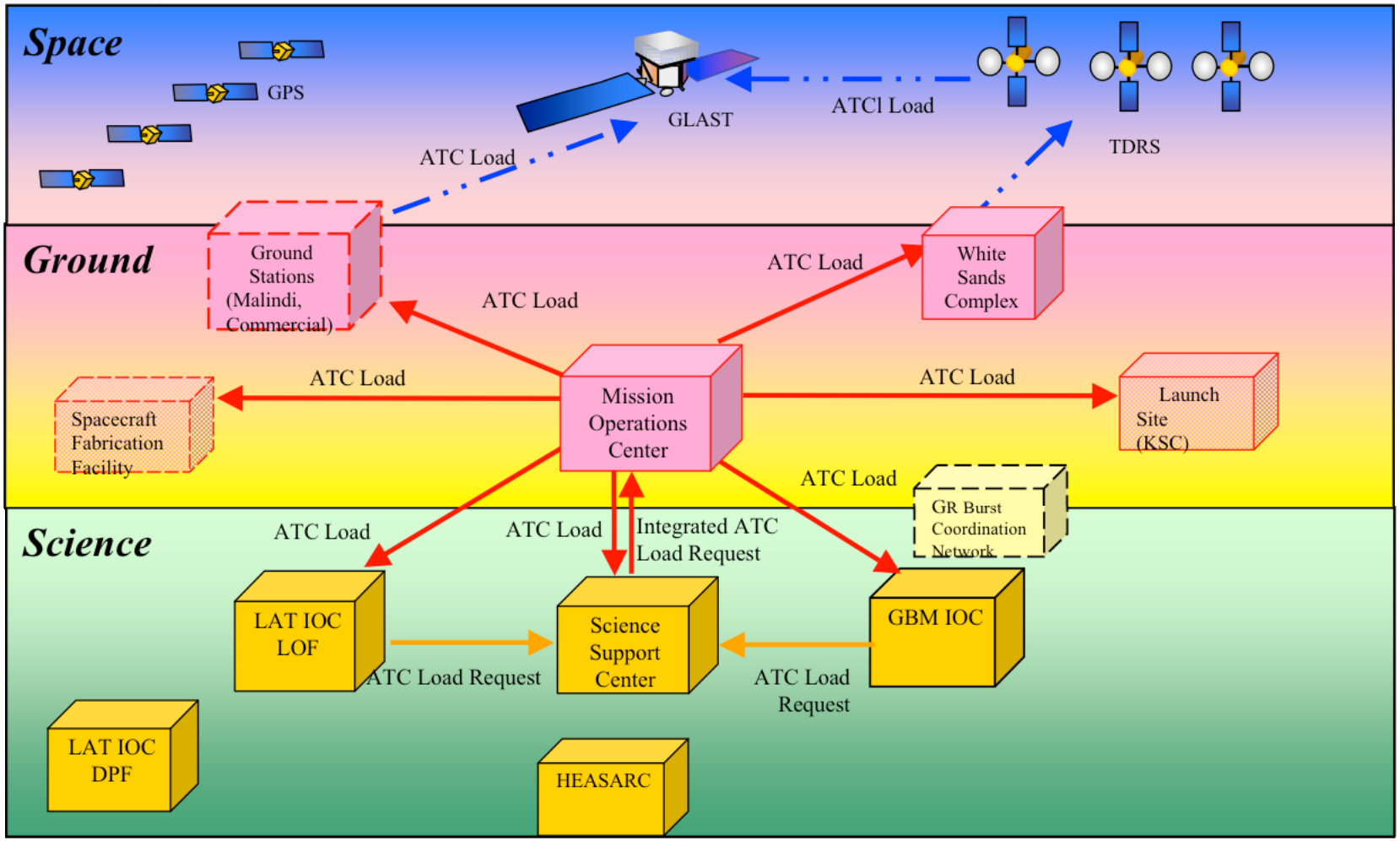
Real Time Command



- Command that can be sent to the observatory by a human during a real time support
- Used to execute instructions to the observatory that must be sent during a ground contact.
  - Largely configuration oriented
    - SSR management
    - Table dump requests
  - Should Override all other commands in the event of a collision
- Normally all R/T commanding follows strict pass plan
  - Raw commanding is discouraged, most commanding will be done through command procedures for repeatability and reliability.
- Frequency, Timing , Latency
  - Real time command opportunities will occur as many as 4-5 times daily
  - Command to Observatory transit time <= 2 seconds

GLAST Operations Concept

Absolute Time Commands (ATC)

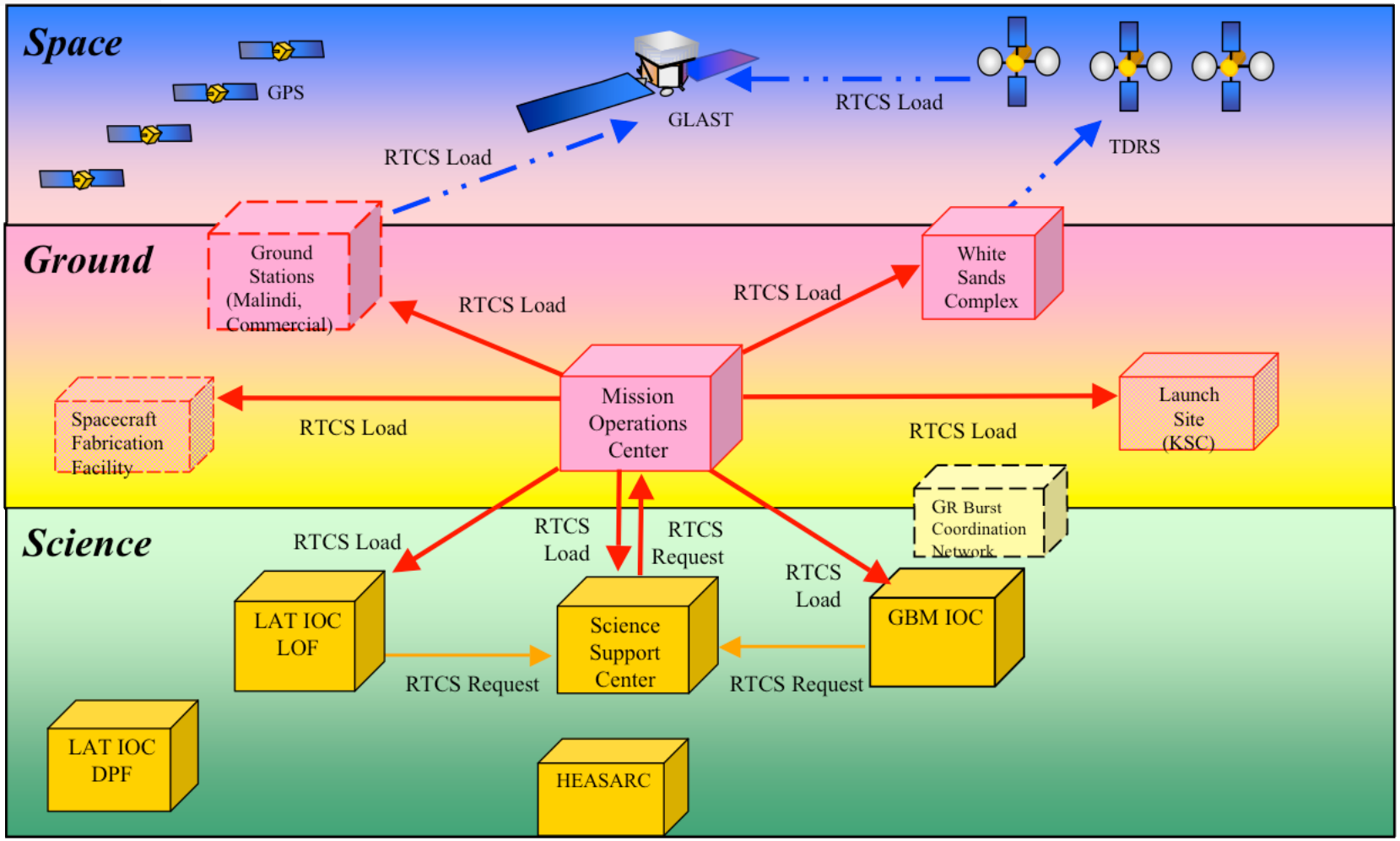


- Series of command/time-tag pairs stored onboard
  - Command executes at associated time
  - Ground system should track the execution on the ground
- Used to execute instructions to the observatory that must occur at a particular moment in time.

- Frequency, Timing , Latency
  - Loads will occur once per week.
  - Latency of command execution will be near the resolution of the onboard clock (very fast)
  - Temporal spacing of commands is vendor specific but should be rather coarse (of order seconds).
    - Precisely time spaced commanding should use RTCSs.

GLAST Operations Concept

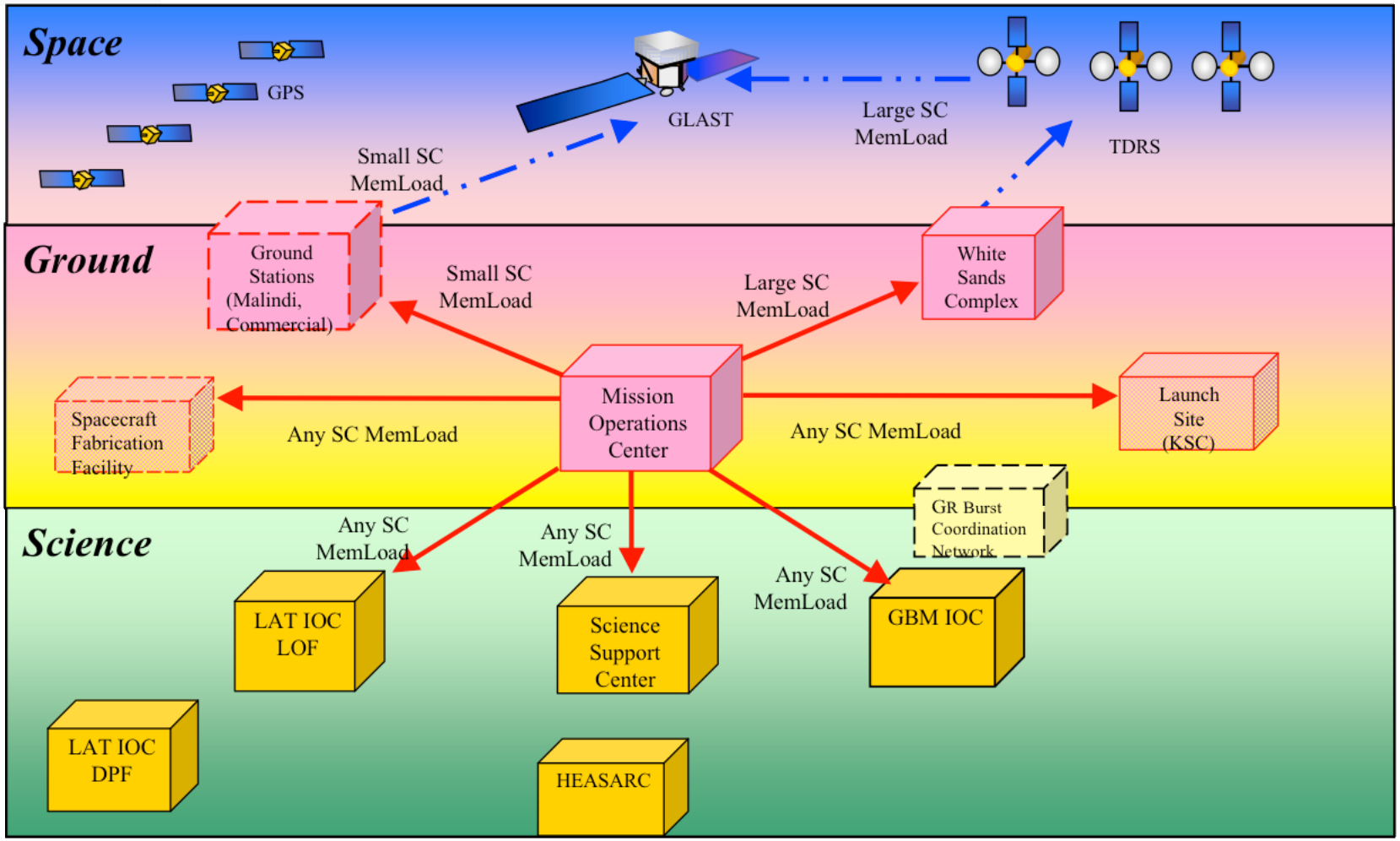
Relative Time Command Sequences (RTCS)



- Series of commands separated by exact time periods stored onboard
  - Initiated with a single (meta-)command
  - Time periods are measured relative to the time the (meta-)command is issued.
- Used to execute a series of commands that require specific time spacing between execution.
  - Useful for complex operations
  - Allow RTCSs to call other RTCSs
  - Telemetry status (active, enabled, disabled, etc)
- Frequency,Timing, Latency
  - Loads will be very infrequent after establishing the baseline set of RTCS (end of check out phase)
  - Latency will be at the resolution of the onboard clock (very fast)

GLAST Operations Concept

Spacecraft Memory Loads



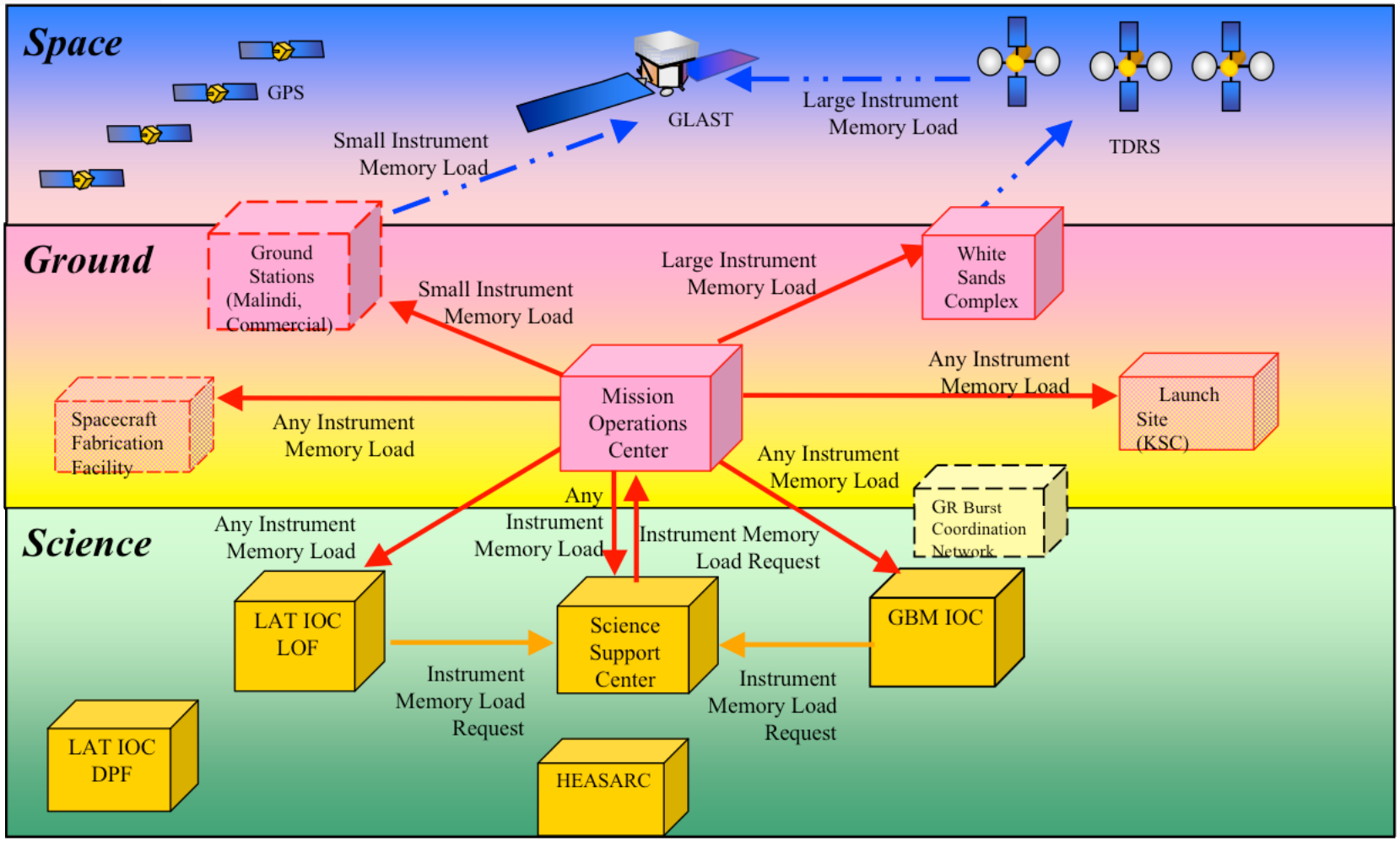
- Software objects that "only" effect the spacecraft operation
  - Tables?
  - Ephemerides
  - Patches

- Used to manage onboard software objects (executable and data)
  - Come in large and small varieties
  - Require ability update while executing

- Frequency, Timing , Latency
  - Large loads will use TDRS for higher rate at longer duration
  - Small loads will use ground stations (perhaps multiple)
  - Relatively infrequent after check-out
    - Frequency depends on what is being loaded

GLAST Operations Concept

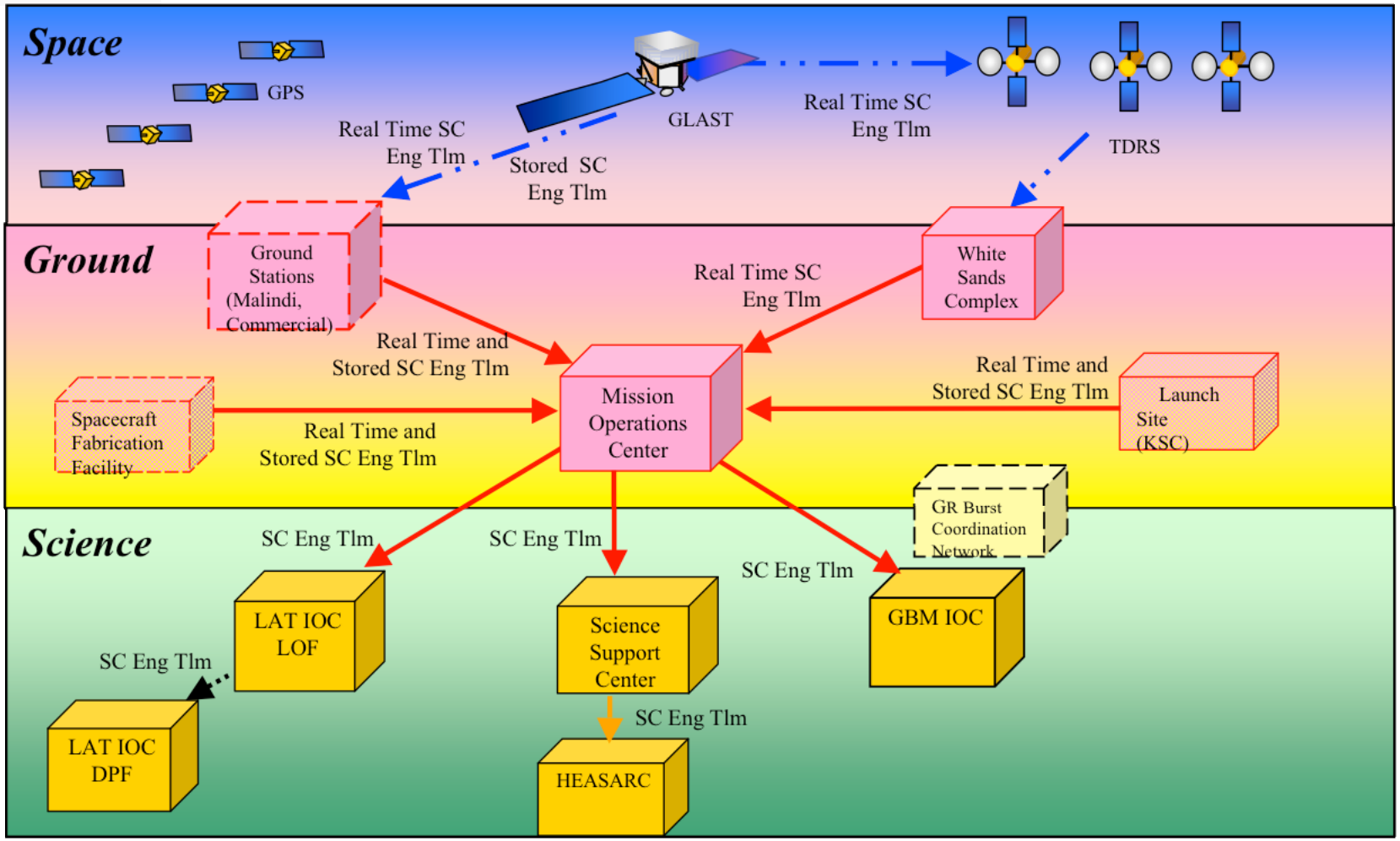
Instrument Memory Loads



- Software objects that “only” effect the instrument operation
- Used by Instruments to assure their functionality
  - Come in large and small varieties
    - Large via TDRS, Small via GN
  - Passed through by spacecraft
- Frequency, Timing , Latency
  - Relatively infrequent after check-out
    - Perhaps weekly or daily under TBD conditions

GLAST Operations Concept

Spacecraft Engineering Telemetry

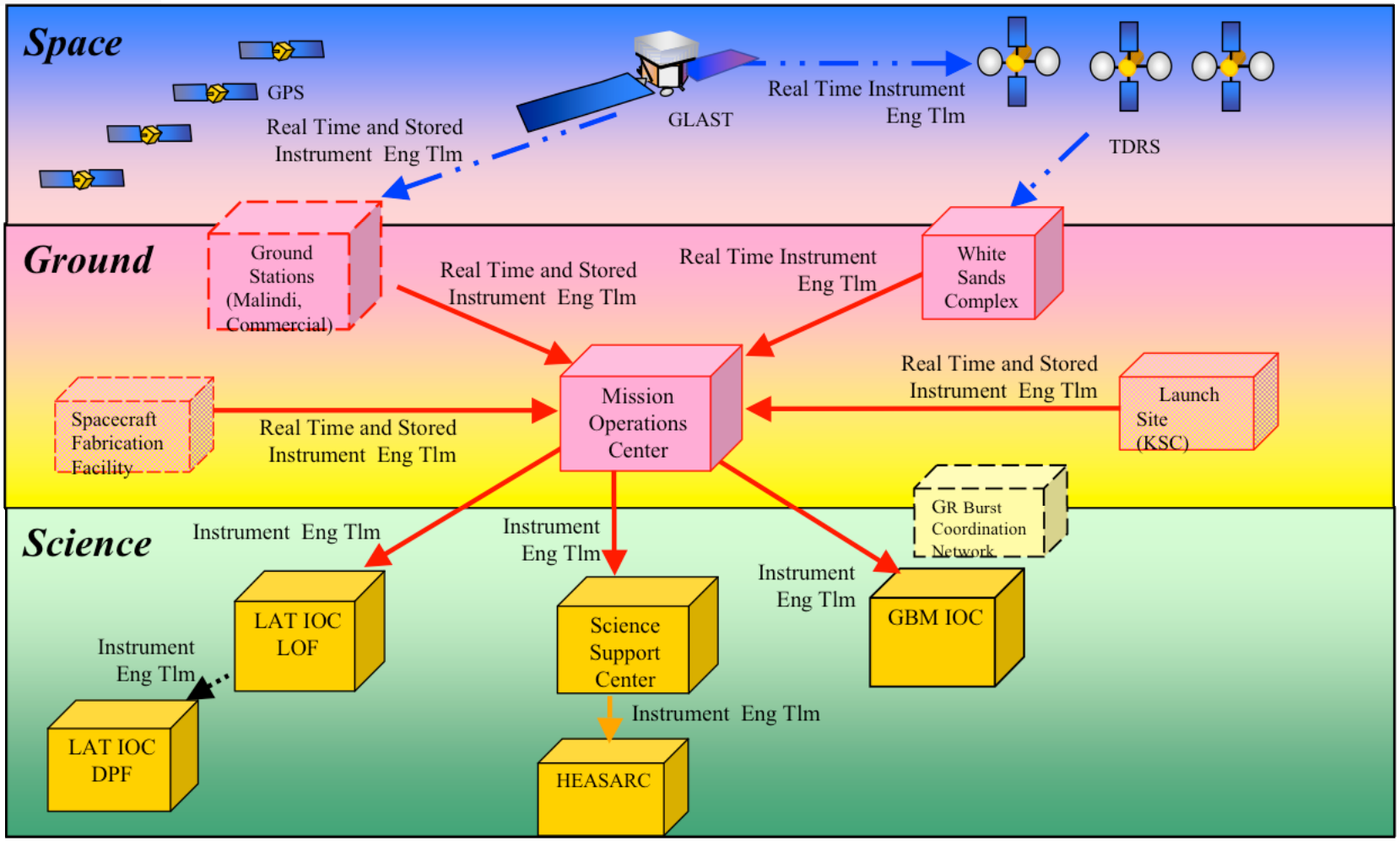


- Data from the spacecraft that describe how it is performing
  - Transducer output, status flags, selected memory location contents, and more!
- Used to monitor Spacecraft Subsystems
  - Real time, stored on board and stored in ground archives
  - Input to daily,weekly, monthly, and lifetime plots
  - Drives realtime display pages
  - Drives onboard Failure Detection and Correction(FDC) Logic

- Frequency, Timing , Latency
  - R/T Telemetry 4-5 times per day
  - Stored used to fill in 24 hour status

GLAST Operations Concept

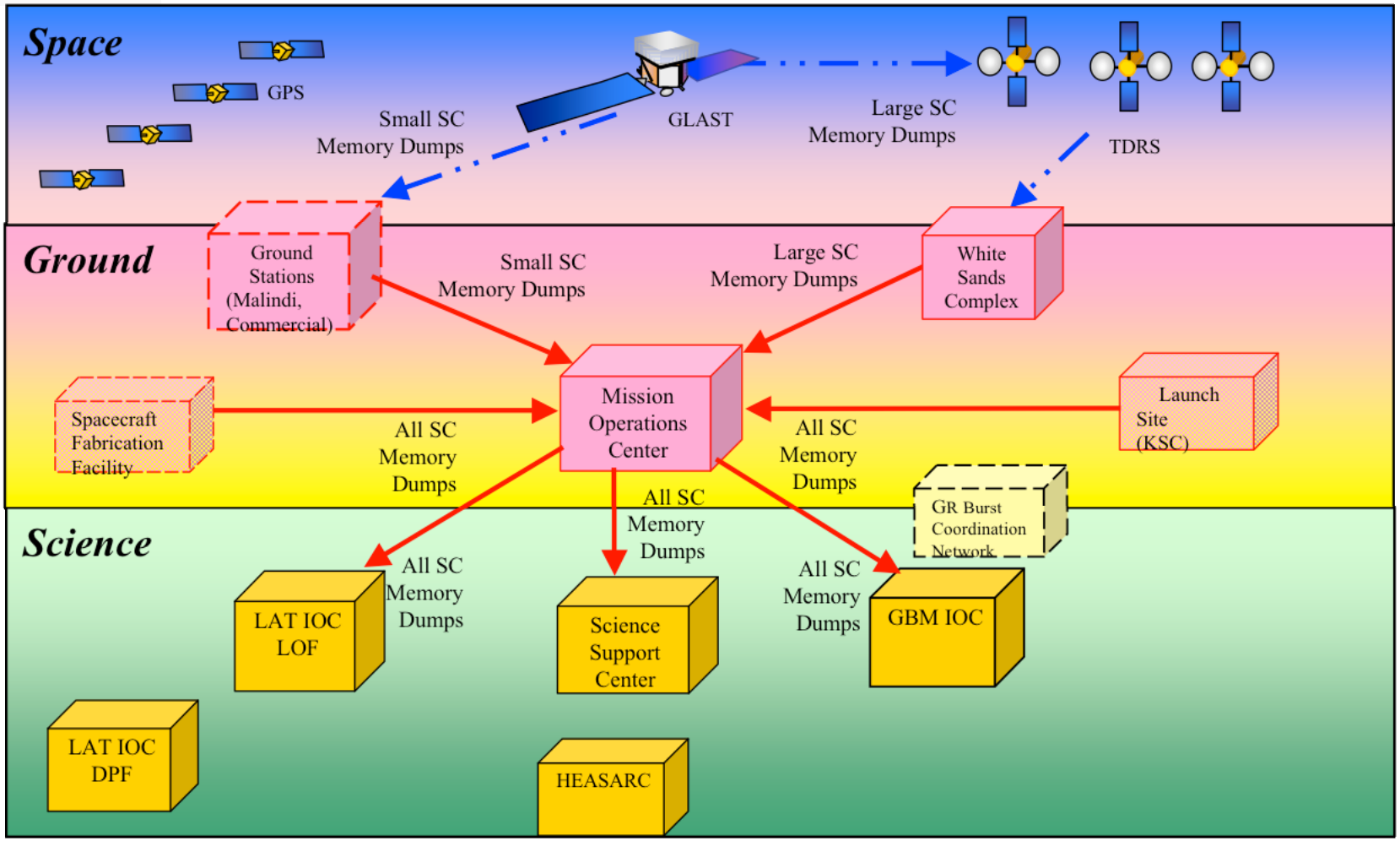
Instrument Engineering Telemetry



- Non-science readouts from the instruments that indicate how it is performing
  - Each instrument gets it own engineering telemetry
- Used to monitor Instrument Subsystems
  - Real time stored onboard and stored in ground archives
  - Input to Daily, Weekly, Monthly and Lifetime Plots
  - Drives realtime display pages
  - Drives onboard FDC logic
- Frequency, Timing , Latency
  - R/T Telemetry 4-5 times per day
  - Stored used to fill in 24 hour status

GLAST Operations Concept

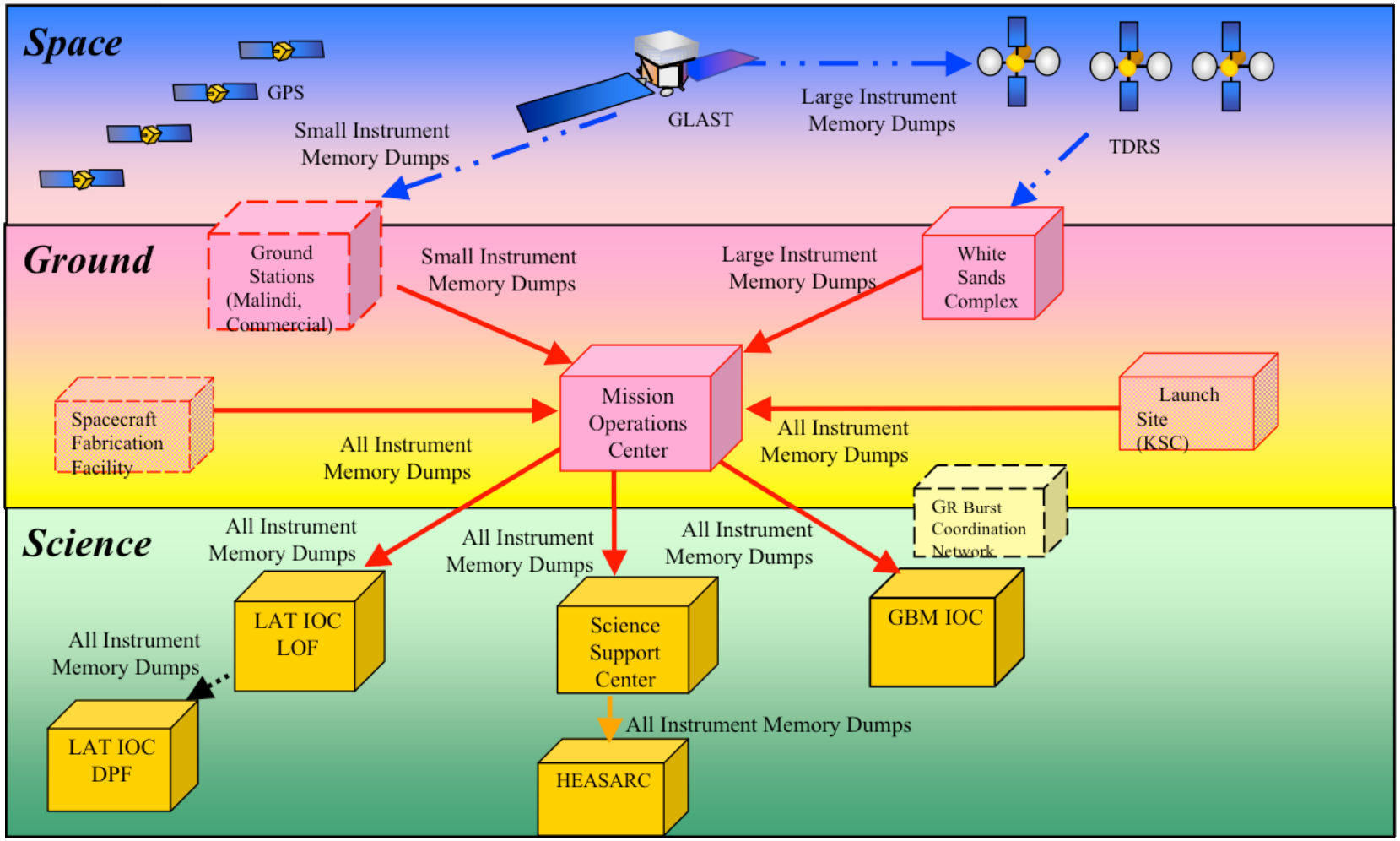
Spacecraft Memory Dumps



- Request from the ground to the observatory to transmit contents of one or more location in spacecraft memory
- Used for
  - Monitoring operations
  - Verifying loads
  - Retreiving onboard logs
- Frequency, Timing , Latency
  - Memory Dumps always follow Memory Loads

GLAST Operations Concept

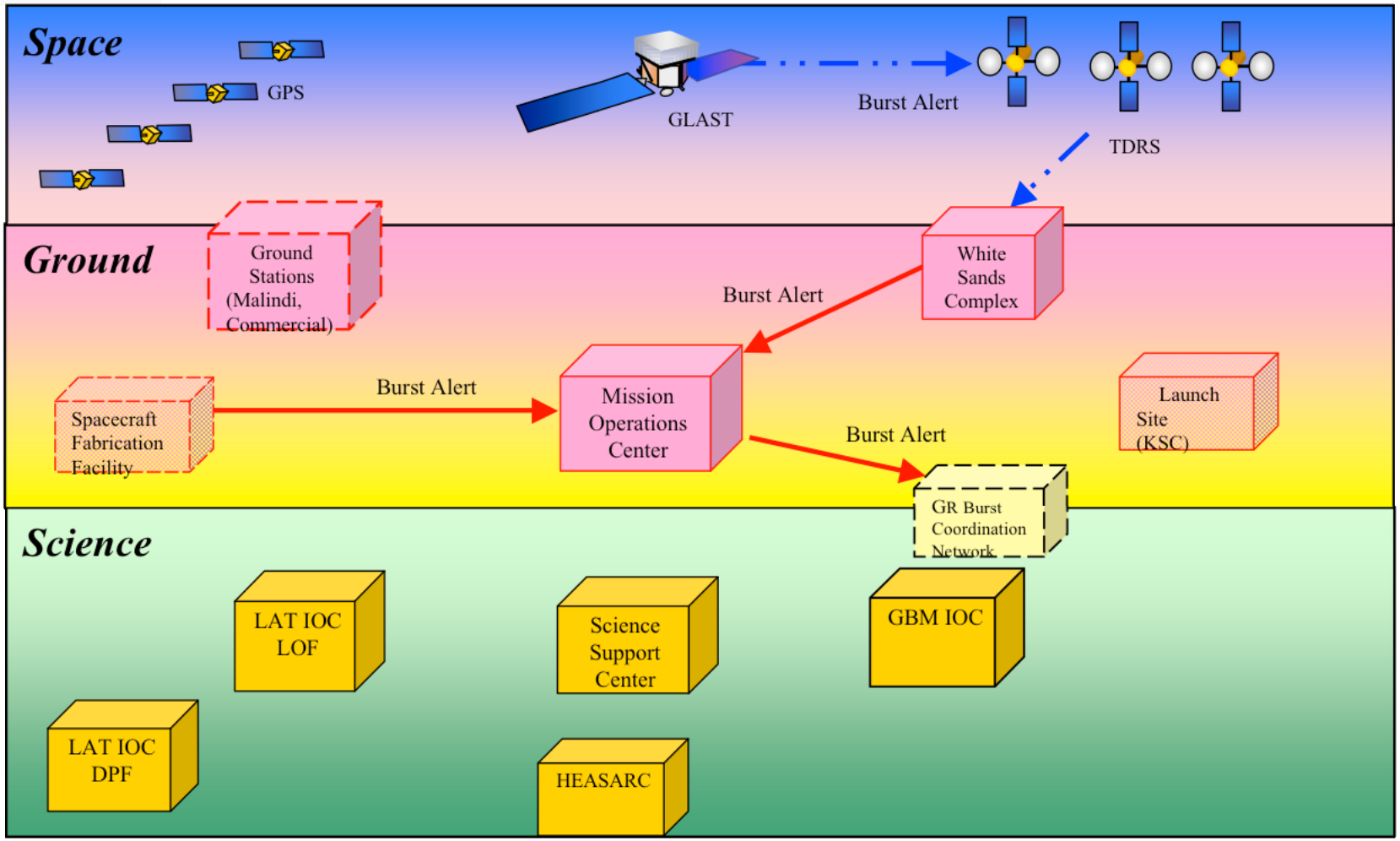
Instrument Memory Dumps



- Requests from the ground to the observatory to tranmit the contents of one or more locations of the instrument memory.
- Used for
  - Monitoring operations
  - Verifying loads
  - Retreiving onboard logs
- Frequency, Timing , Latency
  - Memory Dumps always follow Memory Loads

GLAST Operations Concept

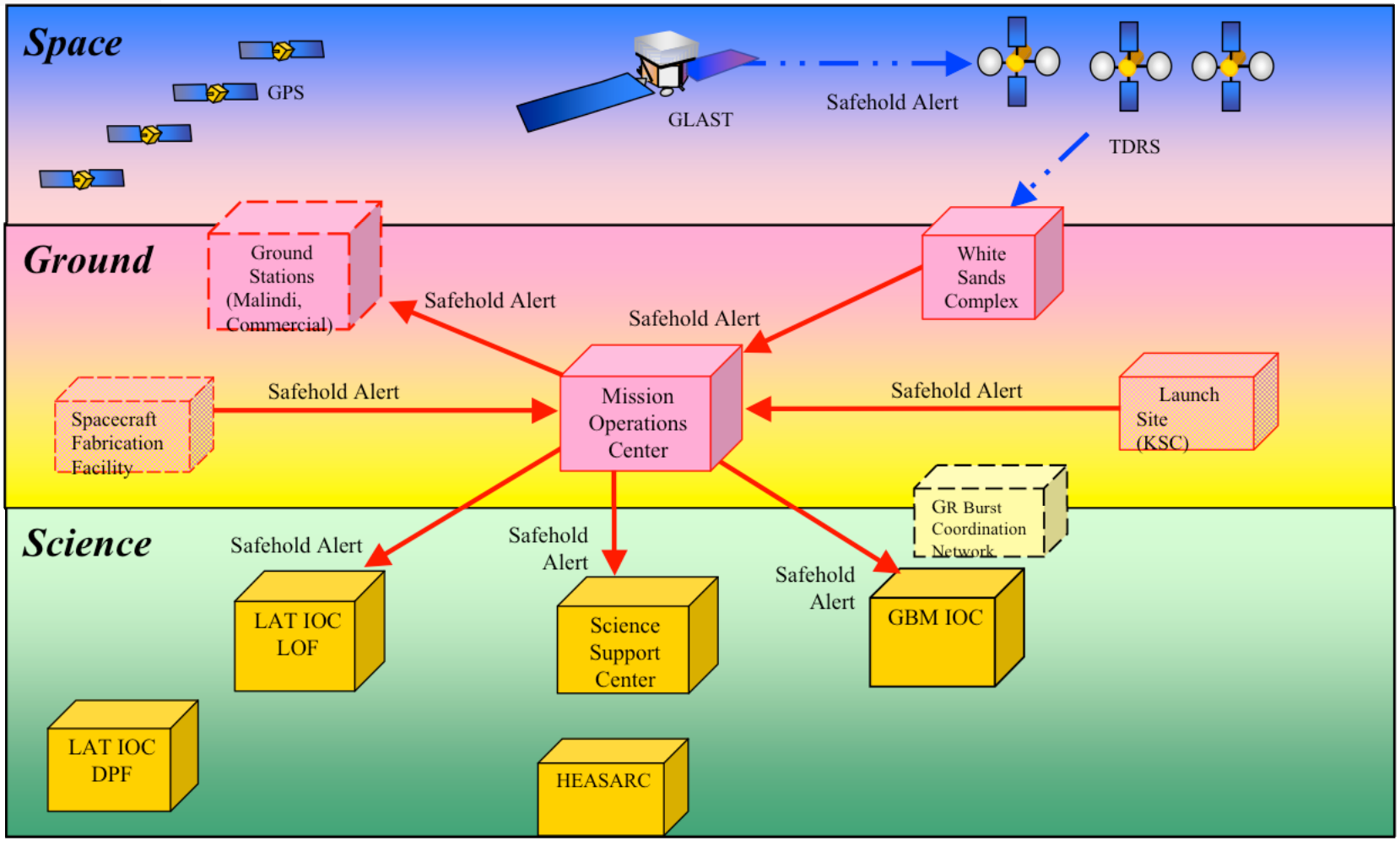
Burst Alerts



- Messages sent when a Gamma-Ray Burst (GRB) with characteristics which trigger the threshold algorithm are observed
  - Messages are operationally of two types
    - Initial alert messages are short with intense response requirements
    - Refinement data message are longer and are not time critical
- Used to notify other observatories world-wide of the occurrence of a possibly interesting burst event.
- Frequency, Timing , Latency
  - Filtered to occur 2 to 3 times per week
  - Initial alert within 7 seconds
  - Refinement data for next ten minutes with +/- 30 second resolution

GLAST Operations Concept

Safehold Alerts

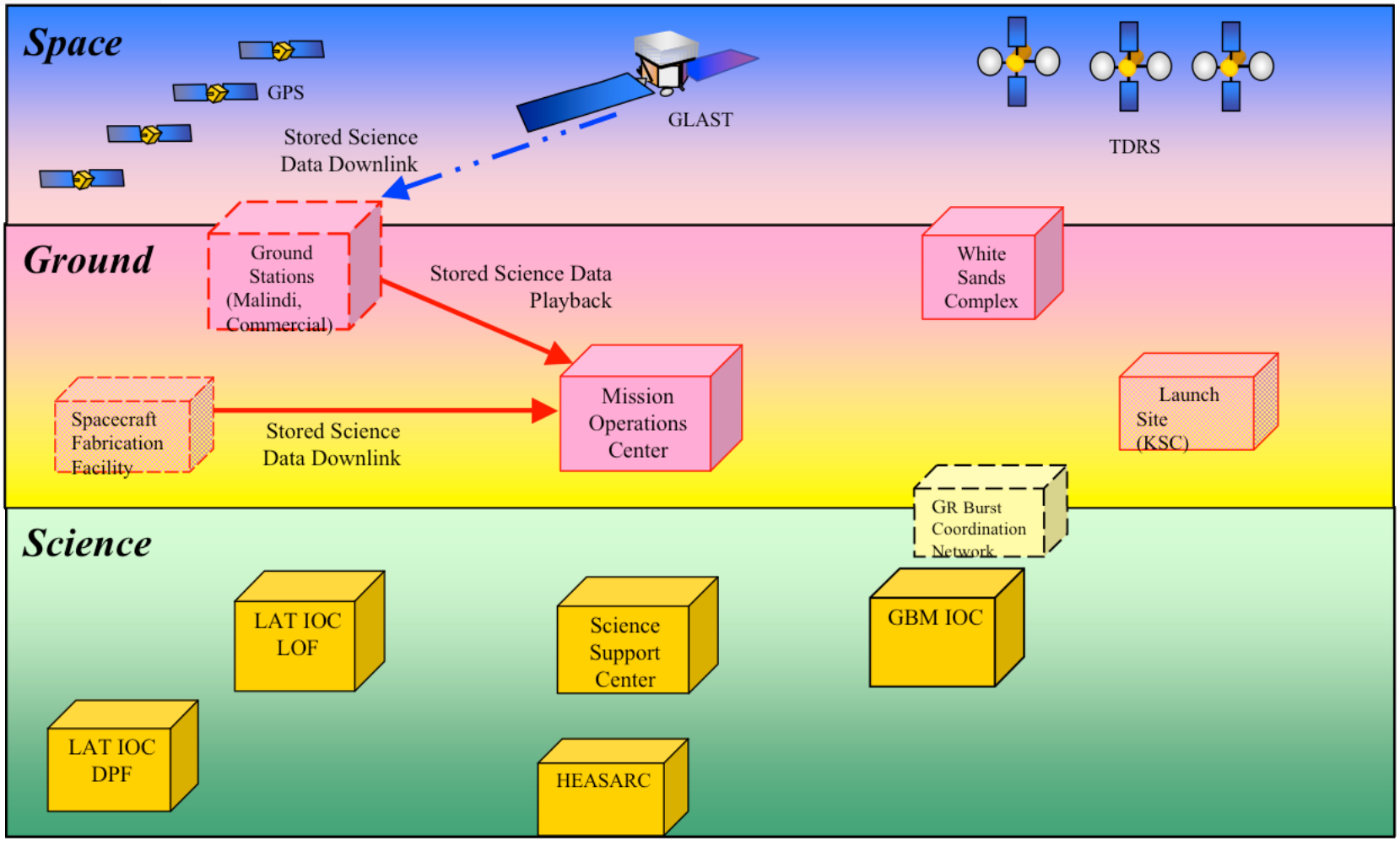


- Messages indicating the observatory has entered safehold
- Used to rapidly respond the cause of the safehold and begin recovery
  - Schedule more supports than normal
  - Begin data analysis sooner

- Frequency, Timing , Latency
  - Spacecraft never go into safehold
  - Rough average about 3 safeholds per 5 year mission- some more, some less.
  - Latency on Alert will be exactly the same as a burst alert after necessary data is collected for the safehold alert.
  - Issue of Latency could be precluded by 24x7 DAS 1 kb engineering telemetry.

GLAST Operations Concept

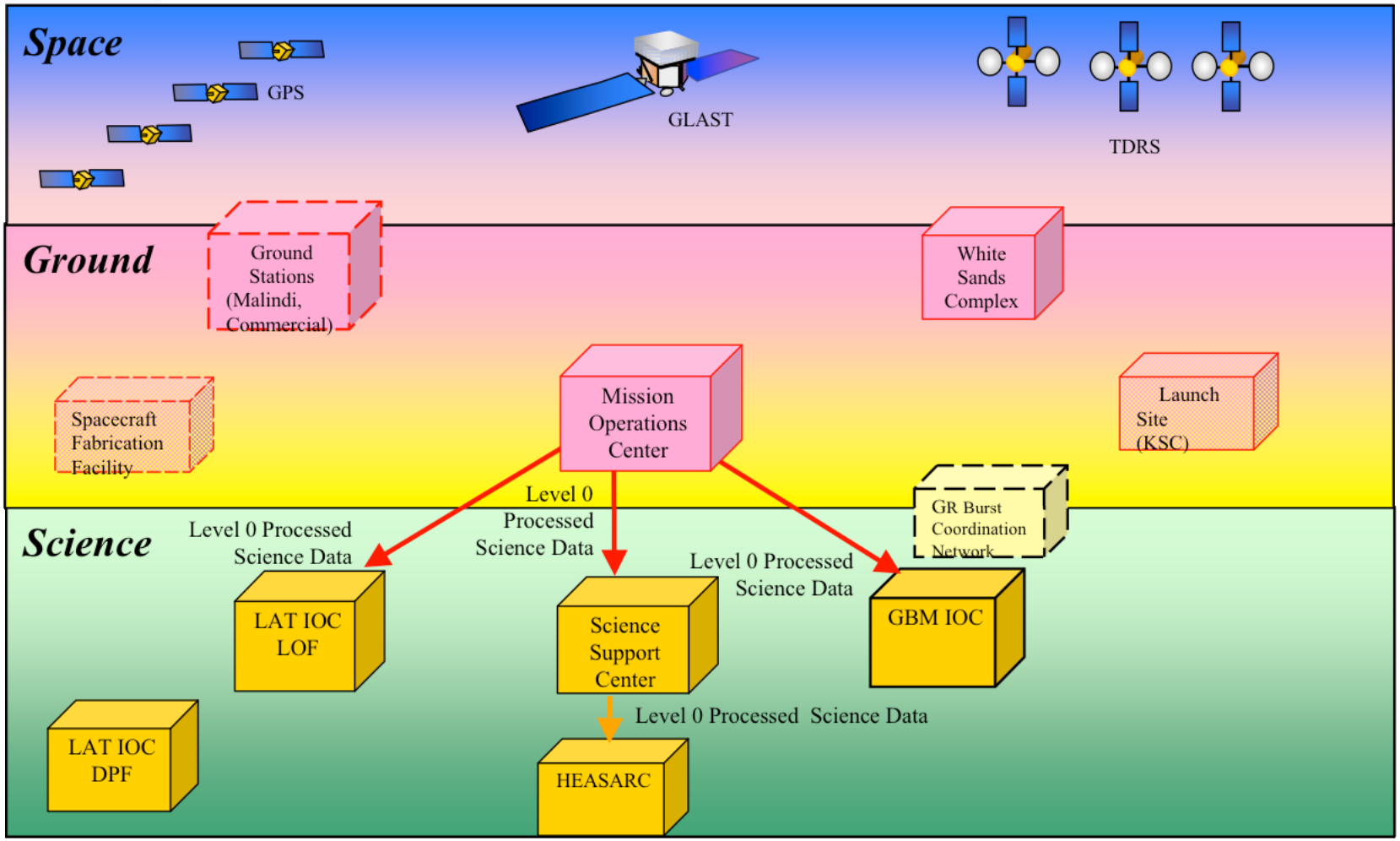
Raw(Unprocessed) Science Data



- Event data readouts from the instruments that have been stored on board.
- Used by Observatory to store events
  - Events = “good” photon detections
- Frequency, Timing , Latency
  - Downlink time and Playback time are not the same
    - P/B Dependent on Ground Link Characteristics and Throughput
  - Mission Requires 4 to 5 downlinks per day
    - Station view dependent
    - Downlink bandwidth dependent
  - Time from receipt of raw at GN to completion of transmit of Level 0 (next slide) from MOC is 12 hours.
  - GN to store 7 days of Raw Downlinked Telemetry

GLAST Operations Concept

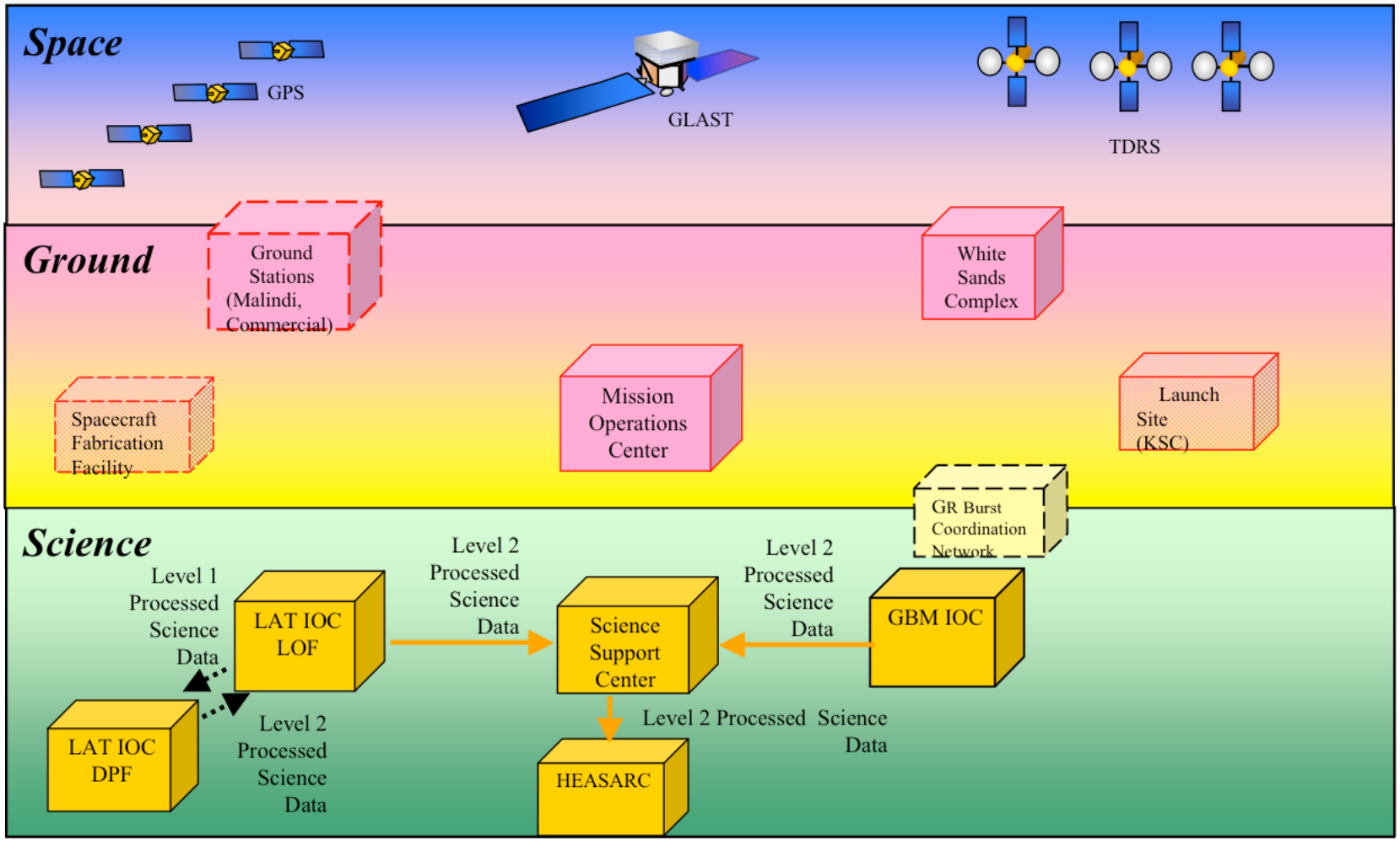
Level 0 Processed Science Data



- Time ordered, non-duplicate, good-block only data sets
- Used by ground system to avoid transmitting useless data to the IOC
  - but MOC will tranmit some cross- dump duplicates and will honor duplicate retransmit requests.
- Frequency, Timing , Latency
  - MOC will be tranmitting this data a lot.
    - Amount of parallel processing will depend on MOC implementation.
  - Time from receipt of raw(previous slide) at GN to completion of transmit of Level 0 from MOC is 12 hours.
  - MOC to store 30 days of Level 0 Data for possible retransmit.

GLAST Operations Concept

Higher Level Processed Science Data



- Level 1 Data
  - Cleaned up Level Zero Data
    - Level Zero is minimally processed for speed and simplicity
  - MOC does not track what has already been delivered to IOC in detail
    - MOC keeps records of what playbacks have been sent to IOC but don't assure there is no overlap in the data content
  - Level 1 has overlaps removed and is the best data set available for Level 2 processing
- Level 2 data
  - Data useful to the science community
  - The Real Data or Data Ready to be Analyzed for Valuable Science Return

- Frequency, Timing , Latency
  - LAT IOC
    - Sends Level 1 data to SAS as is arrives
    - SAS sends Level 2 data back to LAT IOC.
    - LAT IOC sends Level 2 data to SSC with 24 hours of receipt of transmission of Level 0 from MOC.
  - GBM IOC
    - MOC/GBM Data Processing Level definitions are not in synch yet
    - GBM routine data processing is not expected to be overly complex
      - Bursts are their data driver
  - SSC
    - MOC/SSC Data Processing Level definitions are not yet in synch

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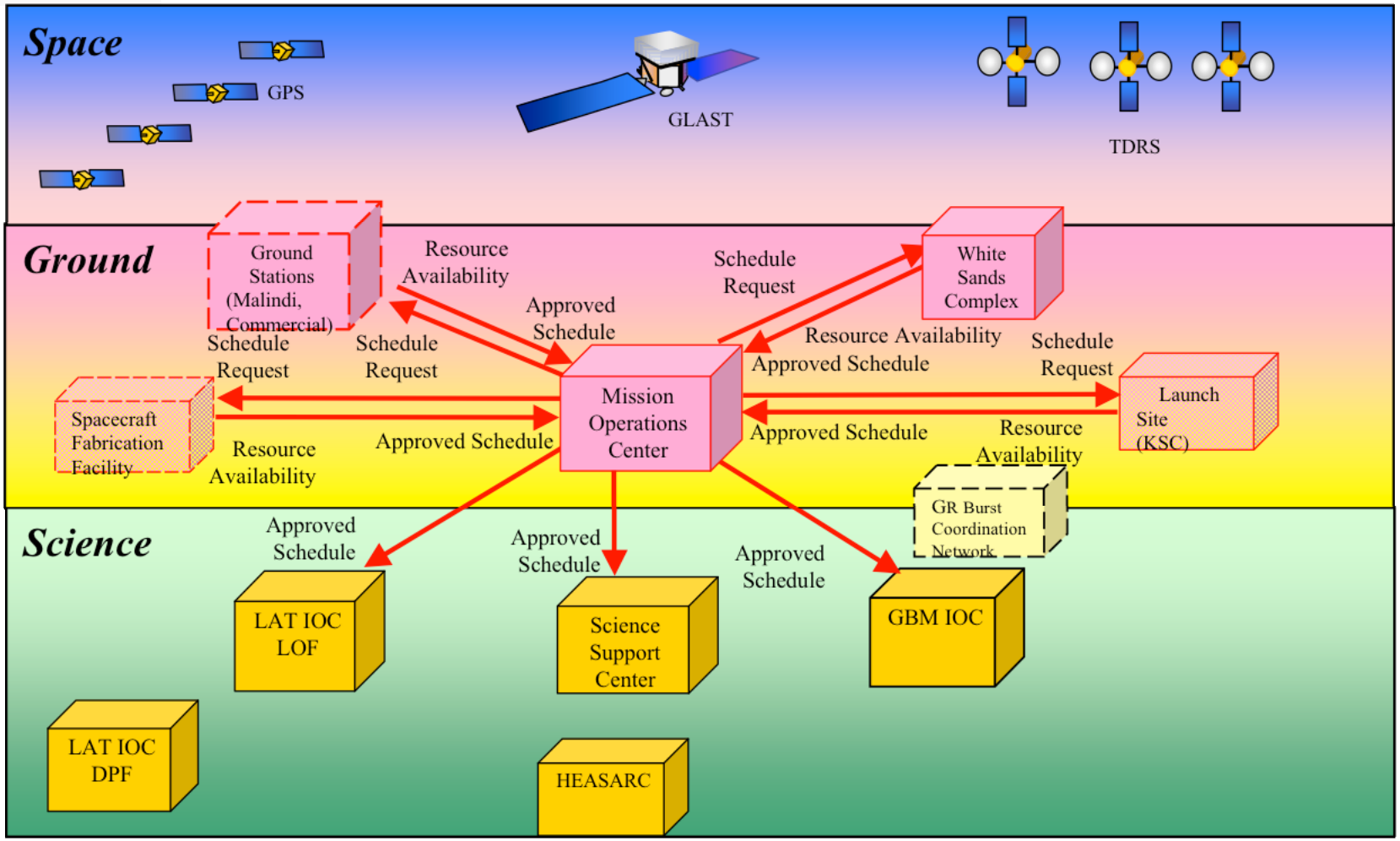
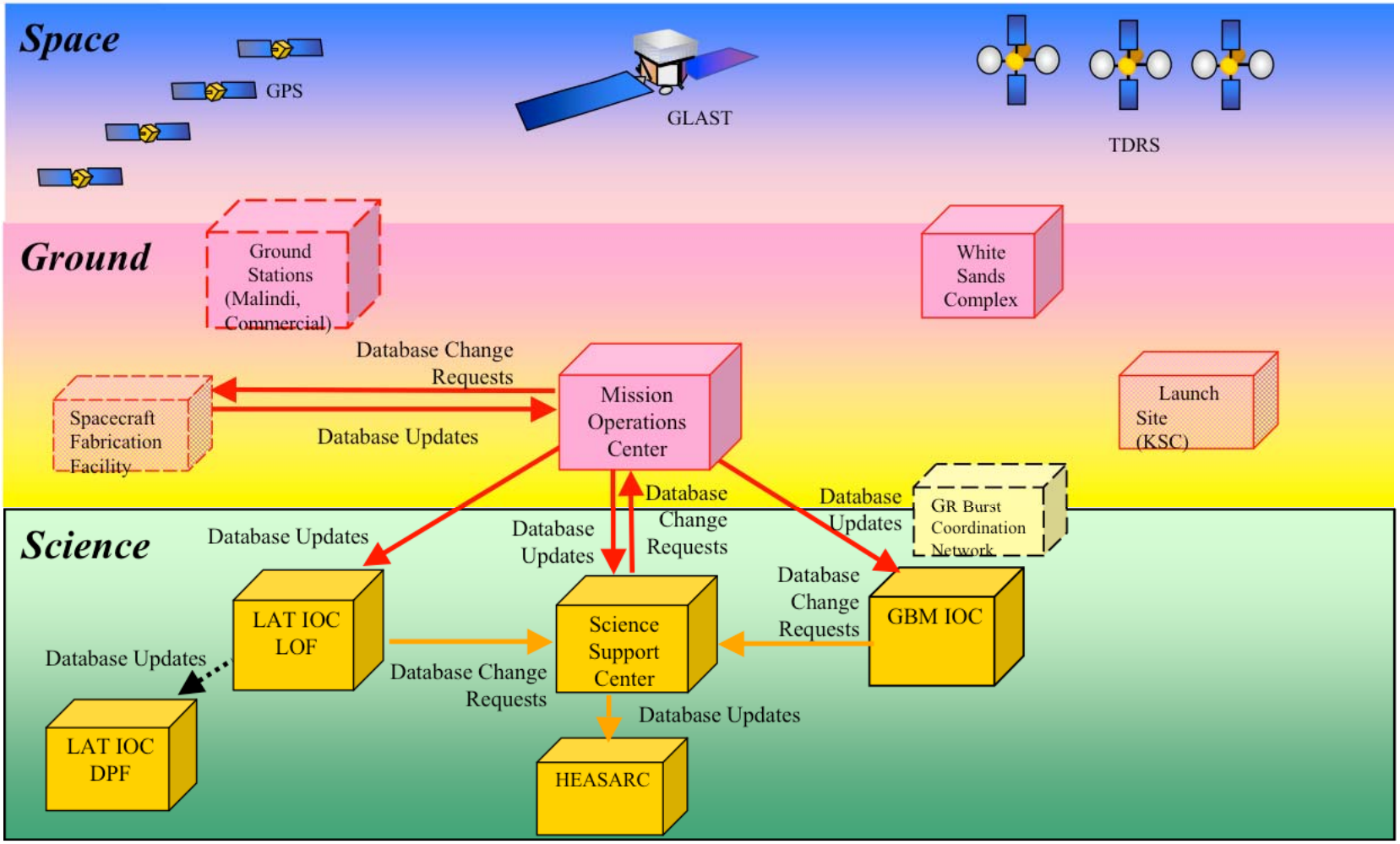
GLAST Operations Concept
Scheduling



- Process of allocating useful ground and space network real time contacts
  - Determination
    - What we need and when we need it
    - What is available
  - Request
  - Arbitration
- Frequency, Timing , Latency
  - Weekly schedule requests
    - Sent from MOC one week in advance of 1st contact requested
    - 48 hour turn around by SN and GN
  - Emergency Requests
    - Turn around within two hours

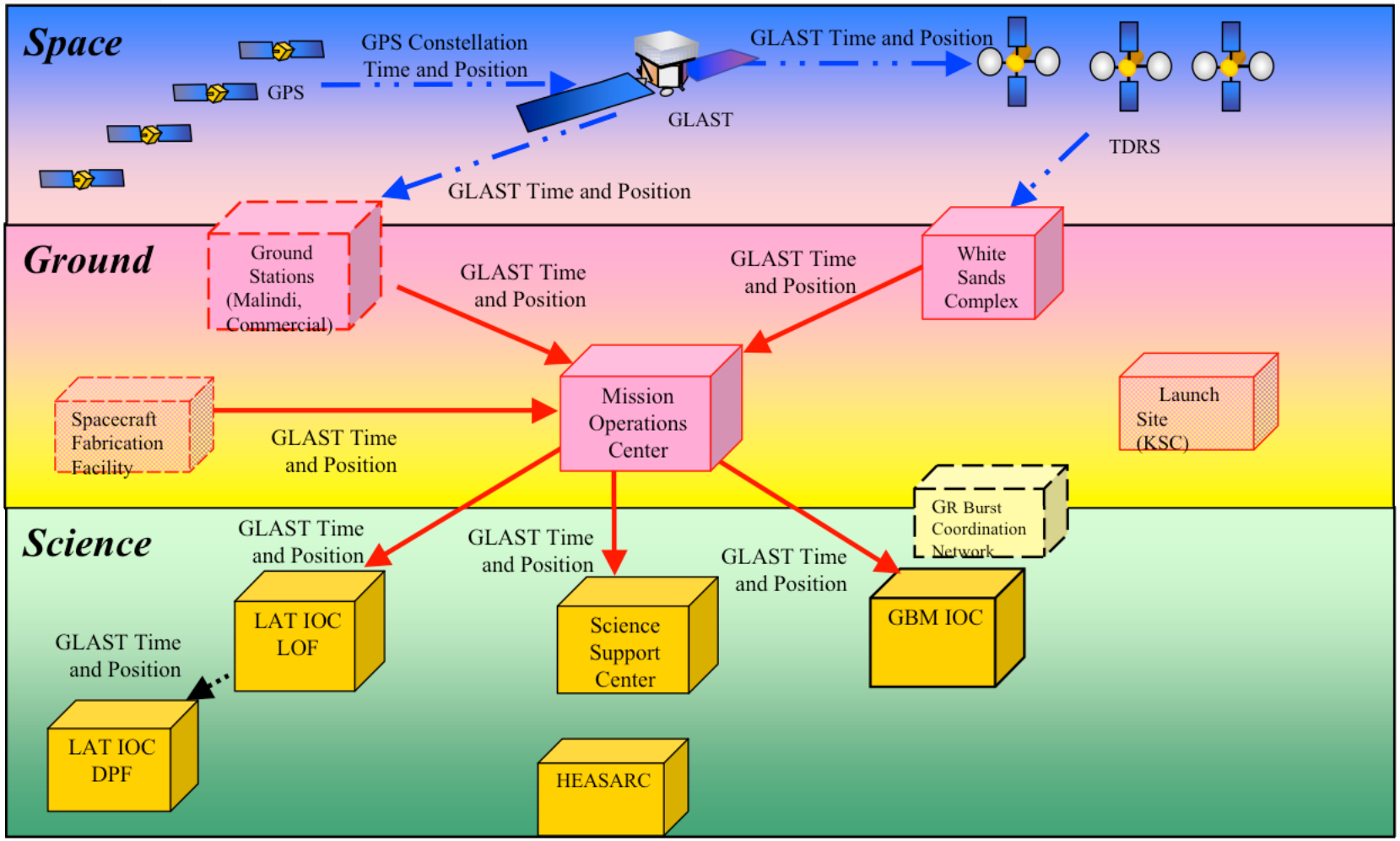
GLAST Operations Concept

Databases



- Ground System components that describe formats of data products
  - Command (pre-requisites, associated telemetry, criticality, restrictions)
  - Telemetry (engineering and science)
  - Calibration Curves
  - Limits (Red, yellow, green)
- Used to allow the MOC to safely command the spacecraft and monitor its activity.
- Frequency, Timing , Latency
  - Implementation Will Synch up with Ground Software Deliveries
  - Frozen at L-60 Days
  - Infrequently updated once on-orbit

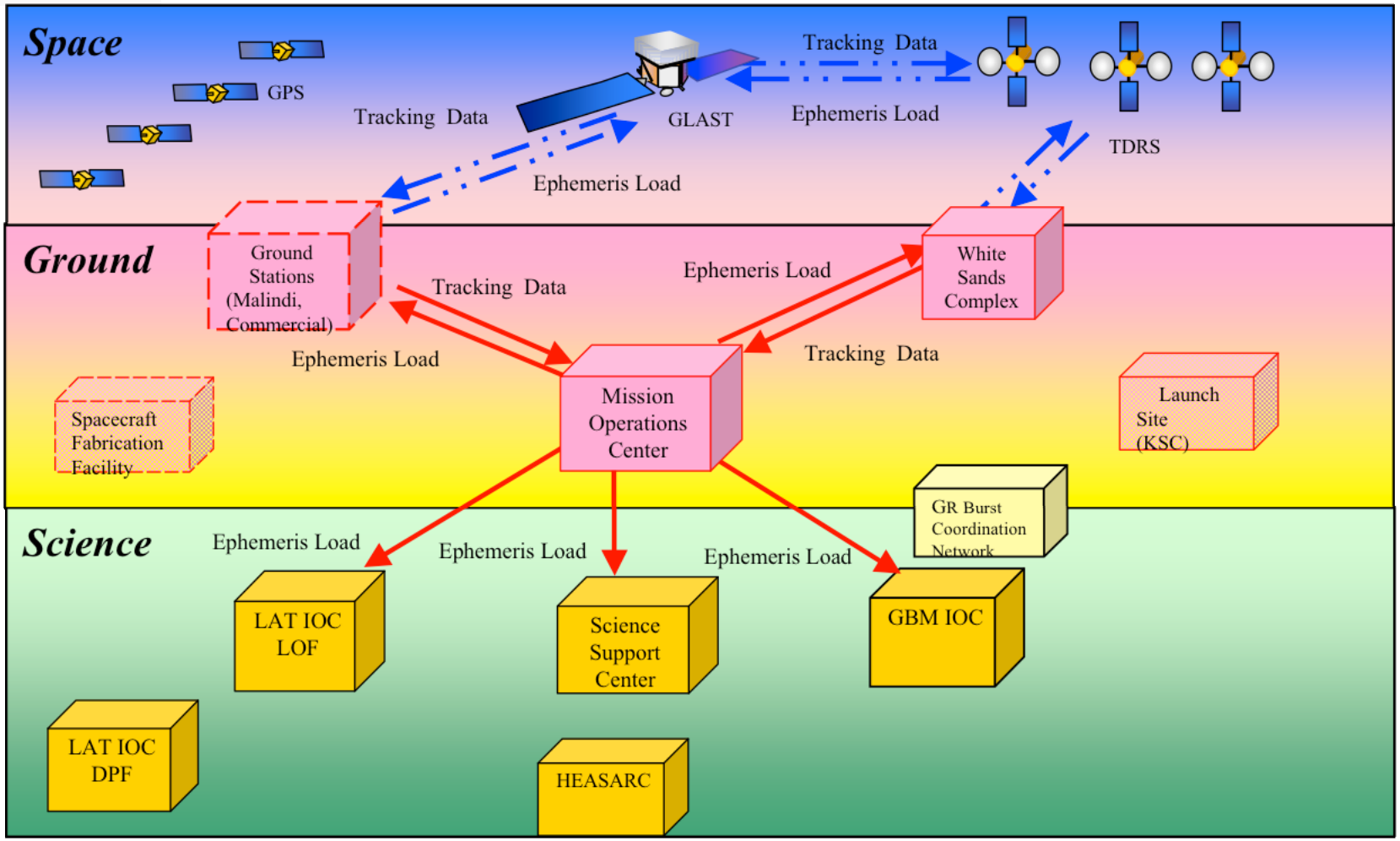
GLAST Operations Concept
GPS

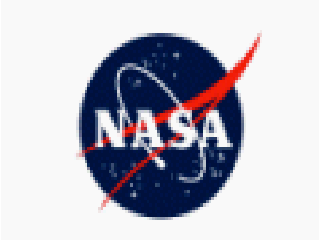


GLAST Operations Concept
GPS

- On board Orbit Determination System in a box
- GPS spacecraft provide their time and position data for the observatory to process into its time and position data
- Frequency, Timing , Latency
  - Boxes take up to 24 minutes to determine a solution from the “Off” state.

GLAST Operations Concept
Ground Based Orbit Determination



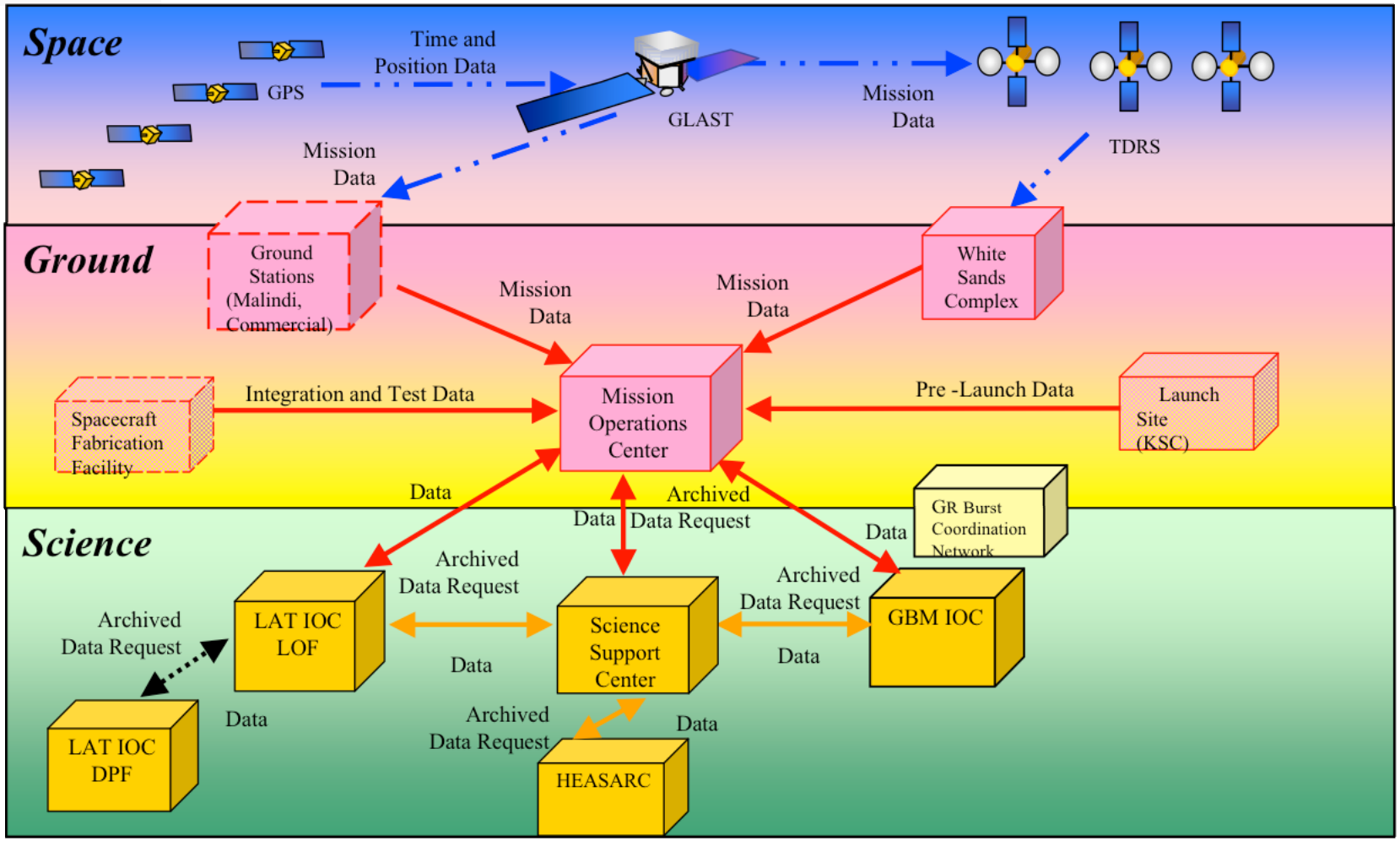


GLAST Operations Concept
Ground Based Orbit Determination

- Ground processing of tracking data to determine the orbit and create product for use onboard
- Tracking data can be delivered from TDRS or Ground Source
- FDF may or may not have a role -vendor specific
- Used as a backup and verification to GPS.
- Frequency, Timing , Latency
  - Requires specially scheduled tracking supports
  - Used extensively during checkout and early orbit
  - Will occur infreqently on-orbit (hopefully)

GLAST Operations Concept

Trending

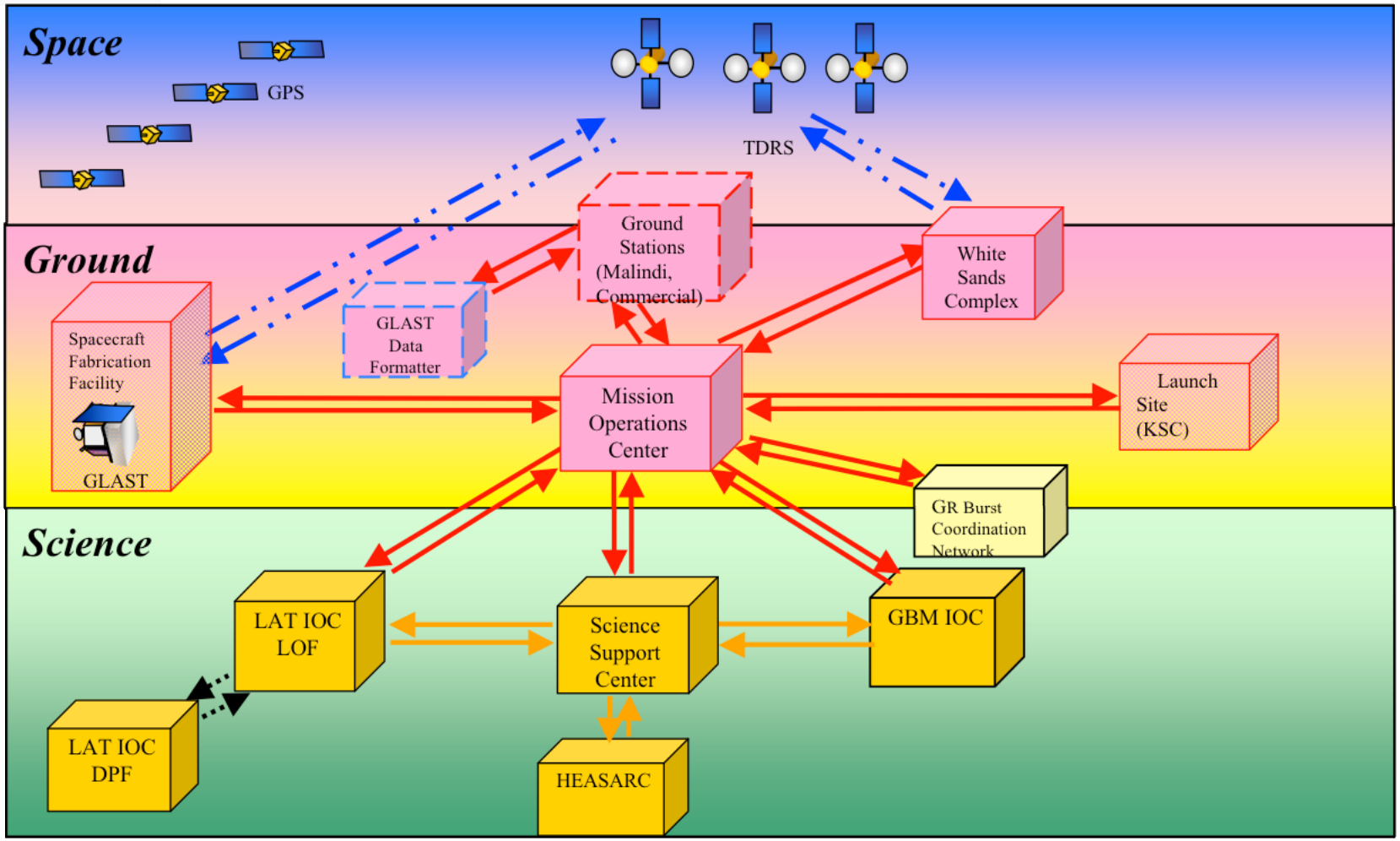


- Process of routinely gathering, processing and distributing the archived data.
  - Each Element will save the data it thinks it wants or needs
  - Elements will be able to request data from other's archives
    - Useful for studying things not thought of a priori that turn out to be interesting
    - Subject to data rights of course
- Used to assess the long term health of the observatory

- Frequency, Timing , Latency
  - Elements will set their own frequency
    - MOC should produce orbital, daily and weekly products at a minimum.

GLAST Operations Concept

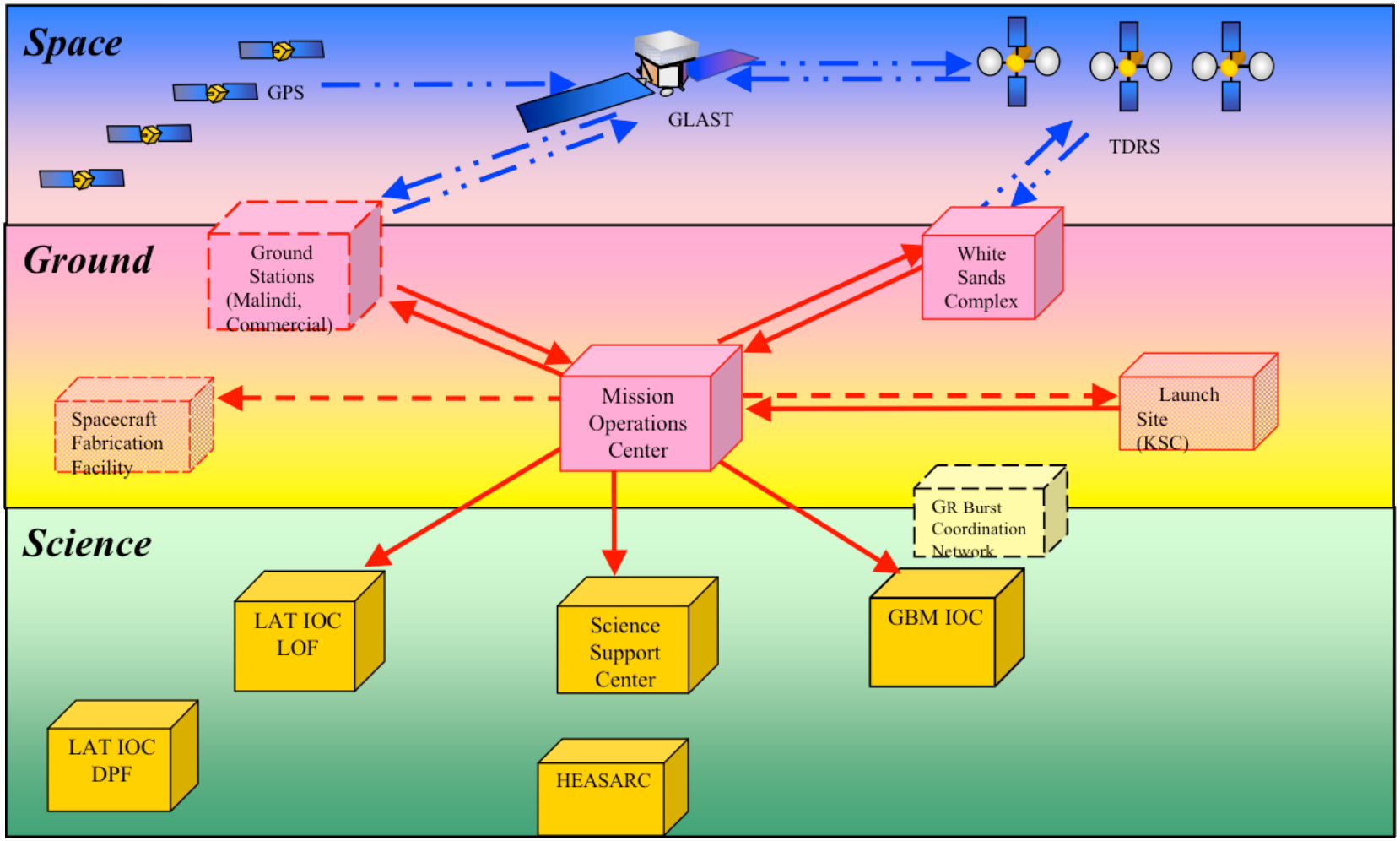
Test Configuration



- Used in pre-launch preparations
- Ground Stations not tested with actual spacecraft
  - Use data formatter for T&C verification of site\
  - Details of how this happens are Vendor dependent
- GPS spacecraft not tested with GLAST
  - Not a risky interface

GLAST Operations Concept

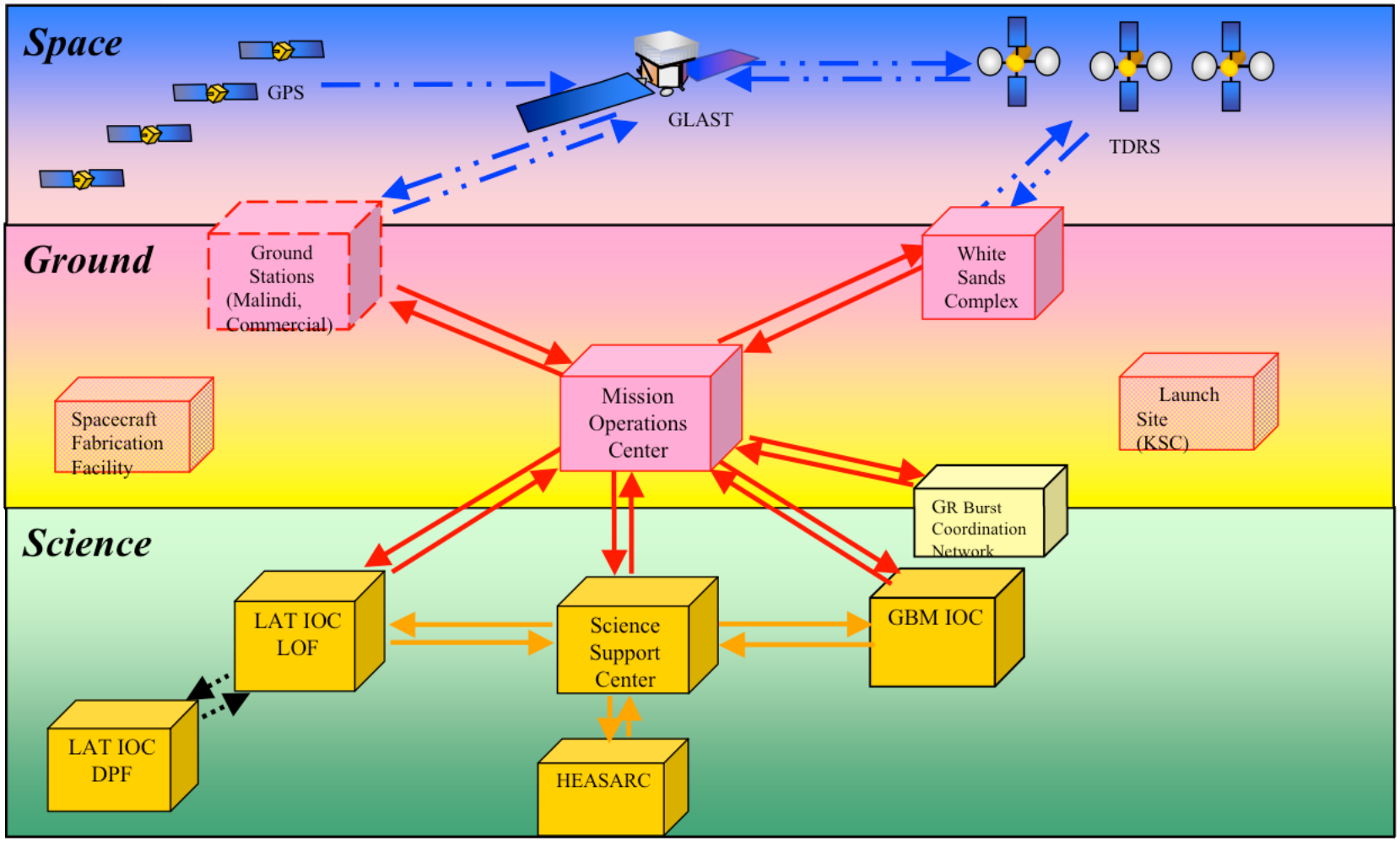
Launch Configuration



- Used from From L-24 hours to L+72 hrs
- Single Dashed lines may terminate well before L-0
- All interfaces are bare bones between elements
  - Engineering Telemetry and Command
  - Sufficient Expertise should be located in the MOC in the event of an unexpected situation - attitude, power, thermal, FSW, etc.

GLAST Operations Concept

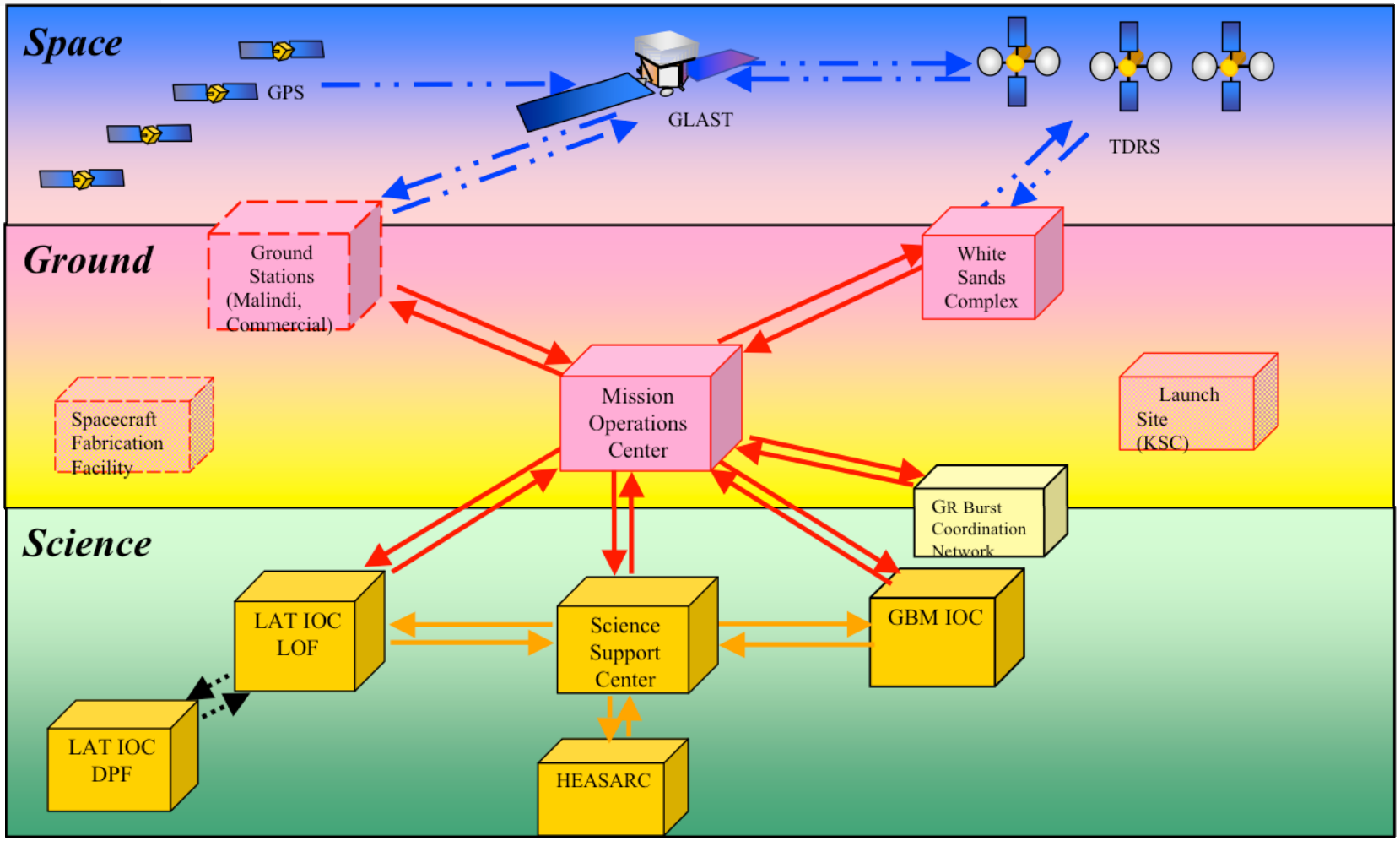
Check-Out Configuration



- Used from From L+72 hours to L+60 days
- Transition from Launch Configuration to Mission Configuration
  - From Engineering Telemetry and Real time Commanding
  - To Science Telemetry and Stored Commanding
- All interfaces are systematically and incrementally activated until all mission products are flowing their appointed routes.

GLAST Operations Concept

Mission Configuration



- L+60 days until De-orbit Decision is Made, Argued and Executed
- All products mentioned in this presentation flow along the paths described
  - Plus some that are yet to be discovered
- All interfaces operate at peak efficiency for a long, long, time!
- De-orbit configuration looks like the end of the checkout period
  - Selected expertise at the MOC to assist with planning the execution